

REQUIREMENTS OF IR SPACE ASTRONOMY

Frank J. Low
University of Arizona

The requirements of Infrared Space Astronomy, like the science itself, are rapidly evolving. This series of Infrared Detector Technology Workshops at the NASA Ames Research Center allows us to trace a critical part of this evolutionary process, by creating a written record, and, at the same time, give us an invaluable opportunity to exchange knowledge, results and new ideas in a timely manner so that progress can occur even more rapidly. In this spirit, the following comments are directed as much at the goals as at establishing requirements. Of course, we all know the difference between the two: when we meet our requirements we are justifiably satisfied, when we meet our goals we are elated.

One way to establish new requirements and goals is to examine those of the past. Indeed, there is now a record of past, present and future IR Space Astronomy missions and it is instructive to examine them in this respect, as in the following table.

Table 1. DETECTORS USED IN IR SPACE MISSIONS

MISSION	DATE	DETECTOR TYPES	SPECTRAL COVERAGE	NUMBER DETECTORS
IRAS	1983	Si,Ge	8-120 um	62
COBE	1989	InSb,Si,Ge, Bolometers	3->1000 um	>50
ISO	1993	InSb,Si,Ge, Stressed Ge	2-200 um	>2K
NICMOS	1995	HgCdTe	1-3 um	500K
SIRTF	1998	*,*	2-750 um	?

At the time of this workshop, the first three major missions listed above are past the stage of reaching for goals and have well established requirements. The fourth mission, NICMOS, is relatively new but is operating on a fast schedule since it is part of an ongoing project, the Hubble Space Telescope; therefore, NICMOS too has well established, though ambitious, requirements. It is the last mission on this list, SIRTf, that is far enough in the future that we can still realistically consider what the goals are and how they will lead to the mission requirements. It is for this reason that much of this workshop will be devoted to topics most closely related to the SIRTf mission.

The top level goals of SIRTf for its imaging arrays are easily stated, given that the wavelength coverage is established at 2 to 750 μm and the unvignetted field of view is 7 arcmin.

- o The field should be fully utilized at each wavelength.**
- o Diffraction should be critically sampled.**
- o Each detector should be background limited.**

The sources of natural background emission in the vicinity of Earth are now reasonably well established and can be used to make useful predictions of photon fluxes for each detector type. This task is beyond the scope of this brief introduction, however, Figure 1 shows the four principle sources of cosmic background sources that limit the performance of the SIRTf instruments. Of special note are the two deep minima in the background levels near 4 and 300 microns. These two "cosmic windows" offer exciting opportunities to explore the early universe since the expansion of the universe redshifts much of the radiation into these parts of the spectrum and because the highest sensitivity is possible within spectral bands centered on these wavelengths. Clearly, detector technologies that allow this great potential of space based telescopes to be realized are those that will be pursued most eagerly.

Finally, it is imperative that very large arrays be developed that meet these sensitivity goals so

that the first two goals may also be satisfied. Of course there is no overriding reason why both of these goals must be met at every wavelength simultaneously; in some cases it may be necessary to use smaller arrays of diffraction limited pixels to sample only part of the available field of view while designing the instrument so that larger arrays, with less sensitivity, can be used to cover the entire field. In this case, the instrument is more complicated and the science return may suffer by some acceptable amount. One of the many benefits of this workshop will be that new results will be presented in a timely manner so that better informed judgments on issues of this type will be possible.

Table 2 is included here to stimulate discussion along these lines. For each octave of the spectrum, the number of pixels required to span the SIRTf field-of-view, assuming a square array geometry, is given in the second column. Arrays of this size would meet the first two goals. In the last column, the results in the second column are translated into a set of requirements for array dimensions that approximate these goals. As a result of this workshop it will be possible to judge which technologies will soon emerge to satisfy these requirements.

Table 2. SIRTf ARRAY DIMENSIONS

LAMBDA (μm)	LAMBDA/2D (pixels)	5X5 ARCMIN ARRAY
2	1200	
4	600	512x512
8	300	256x256
16	150	
32	75	64x64
64	36	32x32
128	18	
256	9	8x8
512	5	4x4

COSMIC BACKGROUND

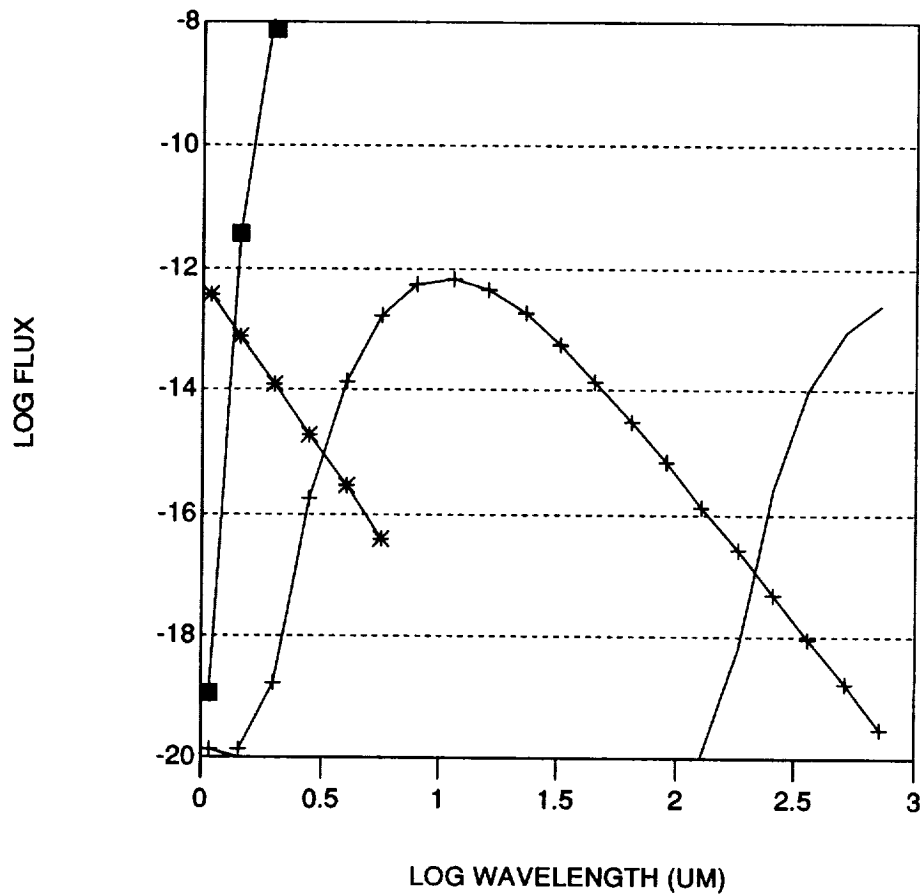


Figure 1. The 4 sources of IR background are: (1) solid squares, ambient temperature emission at an emissivity of 0.05 characteristic of uncooled telescopes such as HST, (2) asterisks, zodiacal light, (3) plus signs, zodiacal emission and (4) solid line, the 2.7 K cosmic background from the early universe. Note the 2 deep minima at 4 and 300 microns.